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RESIDENTIAL EXPOSURE TO 60-Hz MAGNETIC FIELDS FROM APPLIANCES

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A model has been developed which permits assessment of residential exposure to appliance 60-Hz magnetic fields, based on volume and time-averaging of magnetic dipole fields. This approach enables the contribution of appliances to the total residential exposure to be compared to that of other sources. Detailed calculations assuming a linear response, based on previous measurements found in the literature on 98 appliances, show that appliances are not a significant source for whole-body exposure, but may be the dominant source of exposure to body extremities.

1. Introduction

The majority of studies which attempt to link 60-Hz magnetic fields to the development of various forms of cancer in humans lack a method for direct assessment of magnetic field exposure levels [1]. Instead, other indices such as wiring configuration codes [2,3] or spot measurements [4] have been used, with varying degrees of statistical correlation with actual magnetic field densities. A more accurate assessment of exposure can be gained by understanding the nature of the sources of residential and occupational magnetic fields.

The sources of residential magnetic fields can be divided into four general categories: high-voltage transmission lines, distribution lines, building wiring, and appliances. Major advances have been made recently in the modelling of current-carrying conductors in and around occupational and residential sites [5,6]. These models have been successful in predicting actual magnetic field densities due to transmission and distribution facilities and household wiring. There have also been careful experimental measurements of the magnetic fields around appliances [7], which have verified that to good approximation appliances act like point-source magnetic dipoles, with the field intensity falling off as the inverse cube of the distance from the centre of the appliance.

job 16-185-790	file 817.22	date April 30, 1991	report no. 91-89-K

However, controversy exists over the relative contribution of appliances to the total residential field [8]. Figure 1 shows a large variability in field densities from various sources and at various distances from the sources. While power lines and the grounding circuit in houses produce average residential fields on the order of 0.1 μT (1 mG), it is difficult to assess the contribution of appliances. This difficulty is due to three factors: the rapid variation of the field strength with distance, the unknown distance of the subject from the appliance, and the duty cycle of the appliance (how often an appliance is "on" or "off"). In this report we seek to remove the variability in Fig. 1 for appliance sources, by using averaging techniques which take into account these spatial and temporal factors.

When considering proximity, even fields from small appliances can be important. For example, while the field 30 cm from an oven can be as high as 0.5 μT, at 3 cm a hair dryer produces up to 2000 μT [9]. Awareness of these fields is important even in epidemiological work. In one instance, a study by Severson et al [10] indicated a low correlation of adult cancer with electromagnetic fields. By including the use of electric blankets in a re-analysis of the same data, Wertheimer and Leeper [11] altered the results enough to indicate an increased risk with greater exposure. Another, admittedly speculative, study [12] reconciled some of these apparent discrepancies by defining "significant household exposure levels".

In this report we formulate a simple model which permits the calculation of magnetic field exposure levels from appliances, enabling assessment of their contribution to the total residential field. First, the appliance is replaced by a magnetic dipole source. The average spatial field is then obtained by averaging over the volume between two concentric spherical shells defined by the appliance dimensions and the position of the subject with respect to the appliance. Finally the time-weighted exposure level is obtained by considering the duty cycle of the appliance. Detailed calculations using the ensemble of appliances considered by Gauger [7] are used to illustrate application of the model, and to infer order-of-magnitude estimates for exposure levels from specific appliances.

2. Theoretical Background

2a. Magnetic Dipole Fields

An appliance may be treated as a current distribution localized to a spatial region that is small compared to the dimensions of the house. In most appliances the magnetic field source is a motor, a transformer, or a resistive heating element that may be approximated by a single circular conducting loop of radius a, carrying a current I (Figure 2). In spherical coordinates (r,θ,ϕ), the radial and angular vector components of the magnetic field, in SI units, at a point (r,θ), with $r >> a$, are given by [13]

$$B(r) = \frac{\mu_0 I}{2}\left(\frac{a^2}{r^3}\right)\cos\theta \qquad (1)$$

$$B(\theta) = \frac{\mu_0 I}{4}\left(\frac{a^2}{r^3}\right)\sin\theta \qquad (2)$$

where $\mu_0 = 4\pi \times 10^{-7}$ H/m is the permeability of free space. Equations (1) and (2) show that the magnetic field at a large distance away from the current loop is dipole in character. The magnetic dipole moment m of the loop is identified as $m = \mu_0 I a^2/4$, and the magnitude of the magnetic field vector is given by

$$|B| = \frac{m}{r^3}\,(1+3\cos^2\theta)^{1/2} \tag{3}$$

The maximum field for a given distance r occurs when $\theta = 0$ or π, on the central axis of the loop; along this line the field magnitude is $2m/r^3$. In general it can be shown that, at large distances, the field due to a localized current distribution is a dipole field. Furthermore, for any current distribution reducible to a plane current loop, the magnetic moment will be proportional to product of I and the total loop area, regardless of the shape of the loop.

From Eq. (3) we can see that the magnetic field strength increases as $1/r^3$ as a person approaches the appliance. This functional dependence is the reason that the fields in the immediate vicinity of an appliance may be orders of magnitude higher than those produced by power lines.

2b. Average Fields

Equation (3) defines the magnetic field strength due to a local current source as observed by a subject at a fixed distance r from the source. In using appliances, the distance from the subject to the appliance usually varies - throughout the day one may sit closer or further away from a television set, for example. It is therefore useful to describe appliance fields in terms of the volumetric average

$$\langle B \rangle = \frac{\int B\,dV}{\int dV} \tag{4}$$

Here $\int dV$ is the exposure volume defined by r_1 and r_2, the distances defining the closest and furthest approach of the subject to the source, respectively, as shown in Figure 3. With $\mu = \cos\theta$, Eq. (4) becomes [14]

$$\langle B \rangle = \frac{\int_{r_1}^{r_2} dr \int_{-1}^{1} d\mu \int_{0}^{2\pi} d\phi\, \frac{m}{r^3}\,(3\mu^2+1)^{1/2}}{\frac{4\pi}{3}\,(r_2^3 - r_1^3)} = \frac{4.14\, m \ln (r_2/r_1)}{r_2^3 - r_1^3} \tag{5}$$

2c. The Duty Factor

The magnetic field as defined by Eq. (5) describes the average field experienced by a subject moving in the vicinity of an appliance. The total exposure level will also be dependent on how often the appliance is "on" or "off"; obviously, a subject experiences no magnetic field exposure from an appliance that is turned off. Table 1 shows some typical daily usages (in hours) of appliances, calculated from average wattages and the number of kilowatt-hours of electricity consumed per month [15]. The product of the average magnetic field and the daily usage yields one possible metric for exposure level, expressed in μT-hours.

To enable comparison between appliance magnetic fields and those produced by other sources - transmission and distribution lines and grounding circuits - the daily usage (in hours) may be divided by 24 hours to yield a unit-less quantity we call the duty factor F_d. For example, a refrigerator with a daily usage of 12 hours has a duty factor of 50% and a television with a daily usage of 8 hours has a duty factor of 33%. Multiplying the volume average field $\langle B \rangle$ by this factor yields a spatially and temporally averaged value

$$B_{ave} = F_d \times \langle B \rangle \tag{6}$$

Equations (5) and (6) form the basis for our model for calculating exposure levels due to appliance 60-Hz magnetic fields.

2d. The Energy Density

Another quantity that may be of some interest is the root mean square of the field, B_{rms}, given by

$$B_{rms} = \langle B^2 \rangle^{1/2} = \sqrt{2}\, m \left[\left(\frac{1}{(r_2^3 - r_1^3)} \right) \left(\frac{1}{r_1^3} - \frac{1}{r_2^3} \right) \right]^{1/2} \tag{7}$$

The quantity $\langle B^2 \rangle$ is proportional to the energy density of the field, which is used in bioelectromagnetic studies as a measure of the power flow from the field to the biological system. The interaction is a heating effect through eddy current generation in conductive tissue and polarization effects in magnetic materials.

3. Detailed Calculations

3a. Magnetic Dipole Strengths

To illustrate the model for 60-Hz appliance magnetic fields as outlined above, we apply it to the ensemble of appliances surveyed by Gauger [7]. In this work, maximum magnetic field levels as a function of distance from the appliance surface were reported for 98 different appliances of 25 basic types; at least

three different appliances were measured for each device type. Although the survey is far from comprehensive, the sample size ensures the accuracy of any observed trends in magnetic field behavior. Other works on appliances exist [16], but most report only single-spot readings. Gauger's distance-dependent data, however, is ideal for our application. Gauger's maximum-field data may be curve-fitted to the dipole source equation, Eq. (3) with $\theta = 0$,

$$B = \frac{2\,m}{(r_{appl} + d)^3} \tag{8}$$

with the magnetic dipole strength m and the appliance dimension r_{appl} (the distance from the centre of the internal source to the appliance surface) as fitting parameters. Here, d is the distance from the appliance surface to the point where the field is measured. Figure 4 shows some typical data and the fit to Eq. (8) for several appliances, as determined by separate Simplex and Newton-Raphson least-square algorithms. In all cases the fit was found to be excellent.

The results obtained for all the appliances in Gauger's ensemble are summarized in Table 2, which lists the original appliance type designation, dipole strengths, appliance dimensions, and the relative deviation from Eq. (8), defined by

$$\chi = \left(\frac{\sum_{i=1}^{N} [B_i - B_{dipole}(d_i)]^2}{N - M} \right)^{1/2} \tag{9}$$

where B_i are the measured magnetic field strengths at distances d_i, B_{dipole} the corresponding theoretical fields from Eq. (8), N the number of data points and M the number of fitting parameters (in this case, two). χ^2 is the quantity minimized in the least-squares program to obtain the best fit.

3b. Spatial Average

To obtain the spatially averaged field $\langle B \rangle$ we must now define effective volumes for each type of appliance over which exposures occur.

Proximity to most appliances ranges over moderate distances. As a typical example, we take the closest approach (d_i) to be 30 cm and the greatest distance (d_f) to be equal to half of the width of an average home, 3.05 m [17].

A subset of appliances, however, are usually operated at close range. Such appliances are portable, usually small, devices such as hair dryers and shavers. For convenience we will refer to such devices as close-range appliances, and take their operating distance to range from $d_i = 3$ cm to $d_f = 30$ cm. From these

definitions we see that, while all appliances contribute to whole-body exposure, close-range appliances are the primary source of exposure to body extremities, such as the hands and face, in users of these appliances.

For each appliance type, average values for m and r_{appl} were obtained from Table 2. Using the values $r_1 = r_{appl} + d_i$ and $r_2 = r_{appl} + d_f$, as defined above for each type of appliance, we calculated values for the spatially averaged fields $\langle B \rangle$ and B_{rms} as defined by Eq. (5) and (7), respectively. In Table 3 we see that B_{rms} is generally higher than $\langle B \rangle$. In fact, examination of Eqs. (5) and (7) shows that B_{rms} could be substantially different from $\langle B \rangle$ for a different choice of d_i and d_f. However, the heating effects which B_{rms} measures are outside the scope of this report. In the remainder of this report, we therefore refer only to $\langle B \rangle$.

3c. Time-Weighted Average

The duty factor F_d for each appliance type may be obtained from Table 1. This value, multiplied by the spatially averaged field $\langle B \rangle$, yields B_{ave}, the spatially and temporally averaged 60-Hz magnetic field level associated with each appliance.

The results for whole-body exposure are summarized in Table 4, while Table 5 summarizes the results for exposure of body extremities due to close-range appliances.

4. Discussion

The results of applying our model for residential exposure to 60-Hz magnetic fields due to appliances, are summarized in Figure 5.

A convenient way to interpret the quantities derived above is to relate the non-time-weighted, spatially averaged quantity $\langle B \rangle$ with peak exposure to appliance magnetic fields, and to relate the time-weighted, spatially-averaged quantity B_{ave} with long-term, chronic exposure. The health sciences community has not yet established whether either peak or chronic exposure correlate to any health effects. However, if we take the values calculated in Tables 4 and 5 to be typical, we may make several inferences.

For individual appliances, chronic whole-body exposures on the order of up to 0.001 μT are possible; these levels are several orders of magnitude lower than typical exposures from power lines or grounding circuits. Taken as a group, the total chronic whole-body exposure is approximately 0.02 μT, still an order of magnitude lower than from other sources. Peak exposure levels are similarly low.

The contribution of close-range appliances is similarly negligible when assessing whole-body exposure. For exposure to body extremities, however, the situation is different. In this case, close-range appliances constitute individual sources which may be large. Taken together, these appliances contribute a total chronic exposure to body extremities of about 1 μT. This is an order of magnitude higher than the typical residential exposure of 0.1 μT due to other sources. Peak exposures of 100 μT or higher may also be found.

The general trends observed above persist even if we allow the operating range $\{d_i, d_f\}$ for each appliance

in our model to vary. Using Eq. (5) we may define the ratio R of extremity exposure to whole-body exposure to be

$$R = \frac{\langle B \rangle_{extremity}}{\langle B \rangle_{whole\text{-}body}} = \frac{\ln(r_2/r_1)\ (r_3^3 - r_2^3)}{\ln(r_3/r_2)\ (r_2^3 - r_1^3)} \qquad (10)$$

While this equation is written explicitly for $r_{appl} = 0$, it may be generalized for appliances of any dimension. To illustrate the behavior of this equation, let us consider the case when $r_1 = 3$ cm and $r_3 = 305$ cm. We may then plot R as r_2 is varied over the range $\{r_1, r_3\}$. This is shown in Figure 6. What is notable in this figure is that $R >> 1$ for any choice of r_2 within the range $\{r_1, r_3\}$. For $r_2 \dashrightarrow r_1$, the extremity exposure is several orders of magnitude larger than the whole-body exposure. For the limiting condition $r_2 \dashrightarrow r_3$, $\langle B \rangle_{extremity}$ is still one magnitude larger than $\langle B \rangle_{whole\text{-}body}$. This observation is the same for any choice of $\{r_1, r_3\}$, and supports our conclusion that the only significant contribution to residential exposure is due to appliances which are operated at close-range and are associated with body extremities.

We should note that appliances cause high exposure of only a small fraction of the body's tissue. This should be taken into account in the final assessment of any possible risks due to close-range appliances, and may even mitigate the effect of elevated exposures. For example, the risk due to ionizing radiation depends on the total exposure of the body's bone marrow. Since only a small fraction of the total marrow is found in the hands, health physics regulations permit the hands to be exposed to higher radiation levels than the whole body.

Further work should focus on an experimental assessment of close-range appliances. It may be necessary to re-design existing instrumentation to accommodate measurements at body extremities. Dosimeters are usually worn on the waist, and are therefore indicative only of whole-body exposure. They will not be sensitive to the exposure levels at extremities.

We should note, furthermore, a *caveat* with respect to measurements of appliance magnetic fields. In a recent evaluation of instrumentation [18] considerable variability was found in measurements on appliances. This variability was much more than for measurements on transmission lines. Typically, measurements differed by a factor of 3. However, differences of up to a factor of 11 were found when one operator used different instruments, and differences of up to a factor of 16 were found among several operators using the same instrument.

In addition there are other complicating factors in characterizing appliance fields. The probe size may be inconvenient, especially when dealing with small appliances. Movement of the probe or vibration of the appliance may make precise measurements difficult. The increased level of harmonics and the nonuniformity of appliance fields may also complicate measurements. All these factors should be addressed in the design of any experimental assessment of appliance fields. Clearly, however, more work must be done to provide some basis for repeatability in appliance measurements.

The model we have presented above is generally valid for any appliance or any localized piece of electrical equipment. The model can therefore be extended to cover occupational exposure levels due to most electrical equipment, including power tools, computer systems, and even large transformers and motors. The actual fields and exposure levels will differ from the values for household appliances because

of the variations in dipole strength, the longer duty cycles and differences in exposure volumes associated with electrical equipment used in occupational situations. However, the same relationship between extremity and whole-body exposure noted above should still apply.

5. Conclusion

We have presented a model for assessing residential exposure to 60-Hz magnetic fields from appliances. We model appliances as point-dipole sources and then form a spatial average of magnetic field strength by averaging over an exposure volume defined as lying between two concentric spheres centred on the dipole source. An average over time is introduced through multiplication of the spatial average by the fraction of the time that the appliance is on. The model is in general applicable to any electrical appliance, and thus may be used in the assessment of both residential and occupational exposure levels. For close-range appliances such as hand-held tools, the model predicts that exposure to body extremities is much larger than whole-body exposure. The model was applied to Gauger's data on residential appliances and we conclude that appliances do not contribute significantly to whole-body exposure, but that they may be the dominant source of exposure to body extremities.

Acknowledgements

We would like to thank Mr. Bill Jones for providing us with the material on appliance duty cycles, Dr. Stuart Harvey for many useful discussions and for material relating to the variability of appliance field measurements, and Dr. Dave Agnew and Dr. Keith Donnelly for sharing their insights on personal dosimetry and residential fields.

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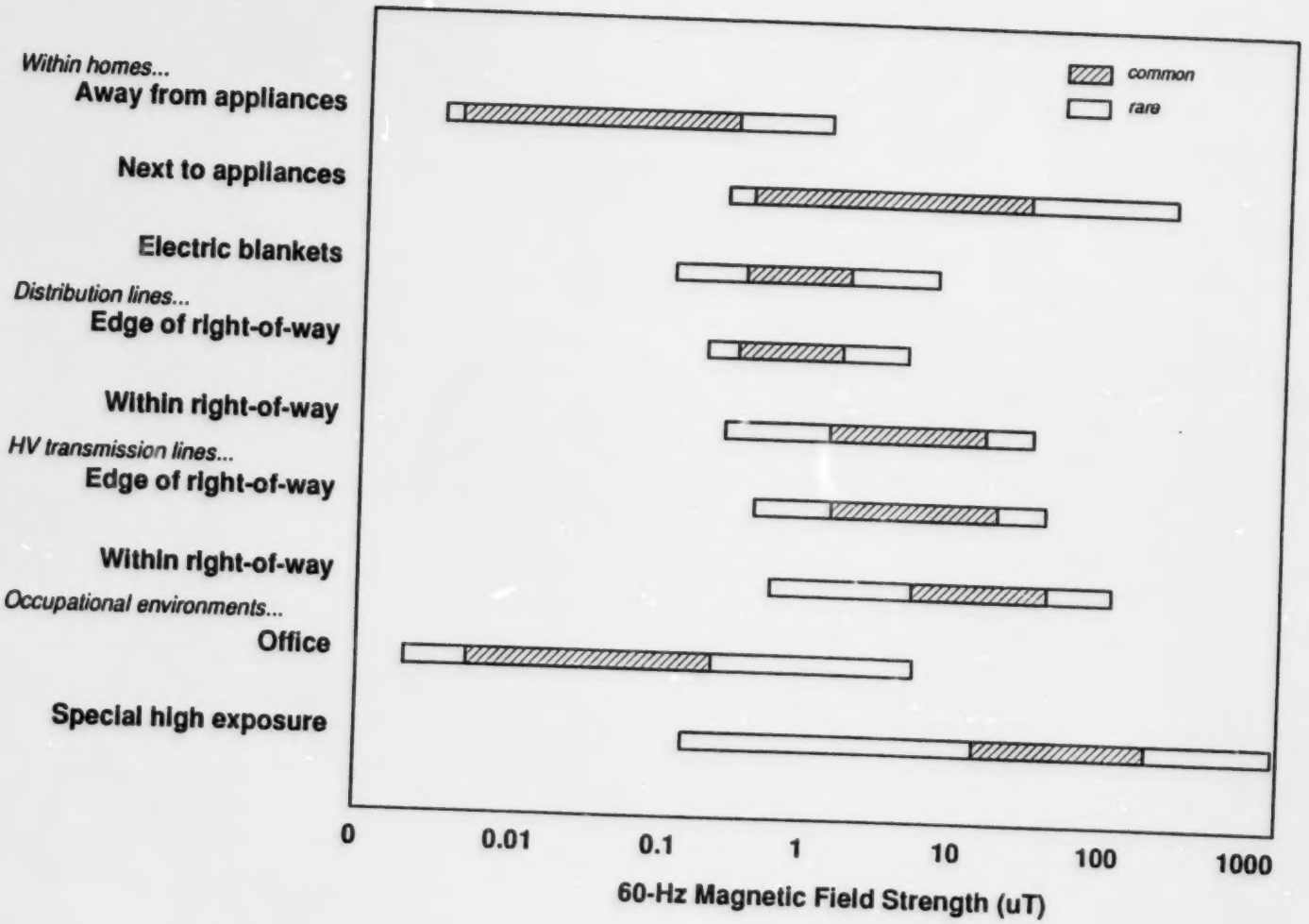

Figure 1. Sources of ambient exposure to 60-Hz magnetic fields.

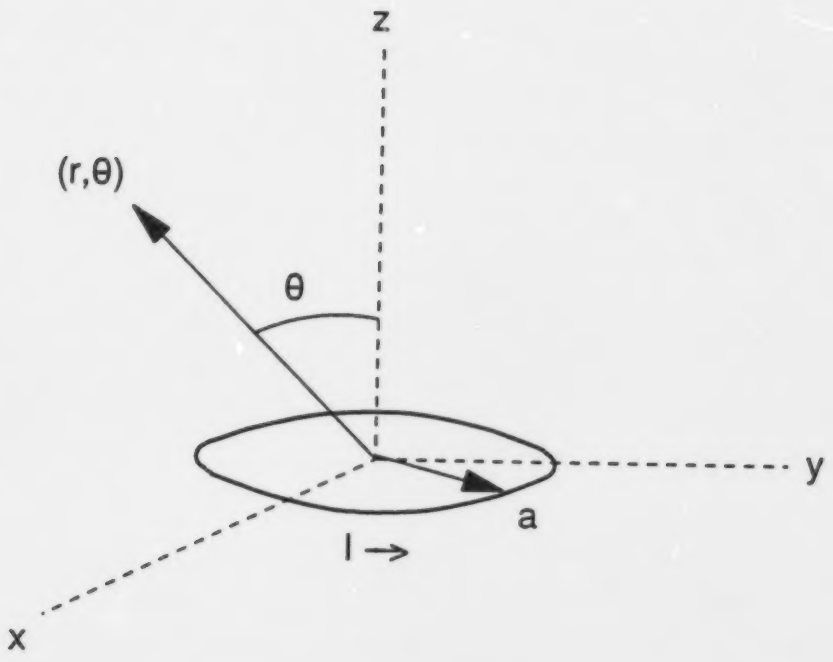

Figure 2. Geometry for a circular current-carrying loop.

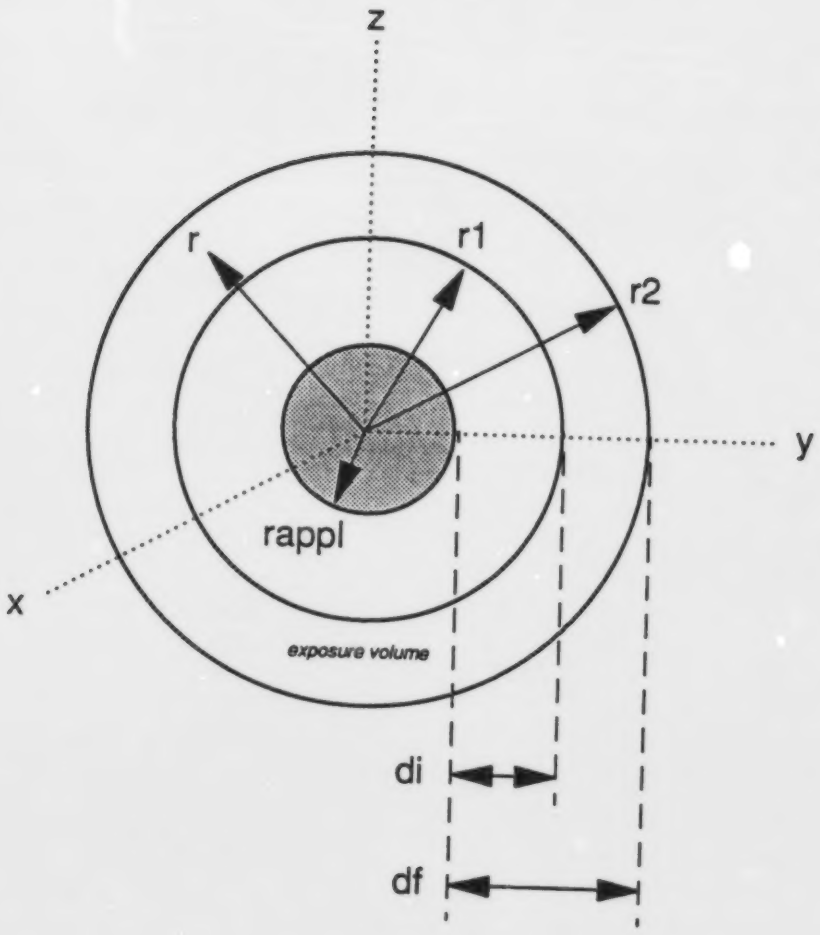

Figure 3. Spherical model for finding spatial average of magnetic field.

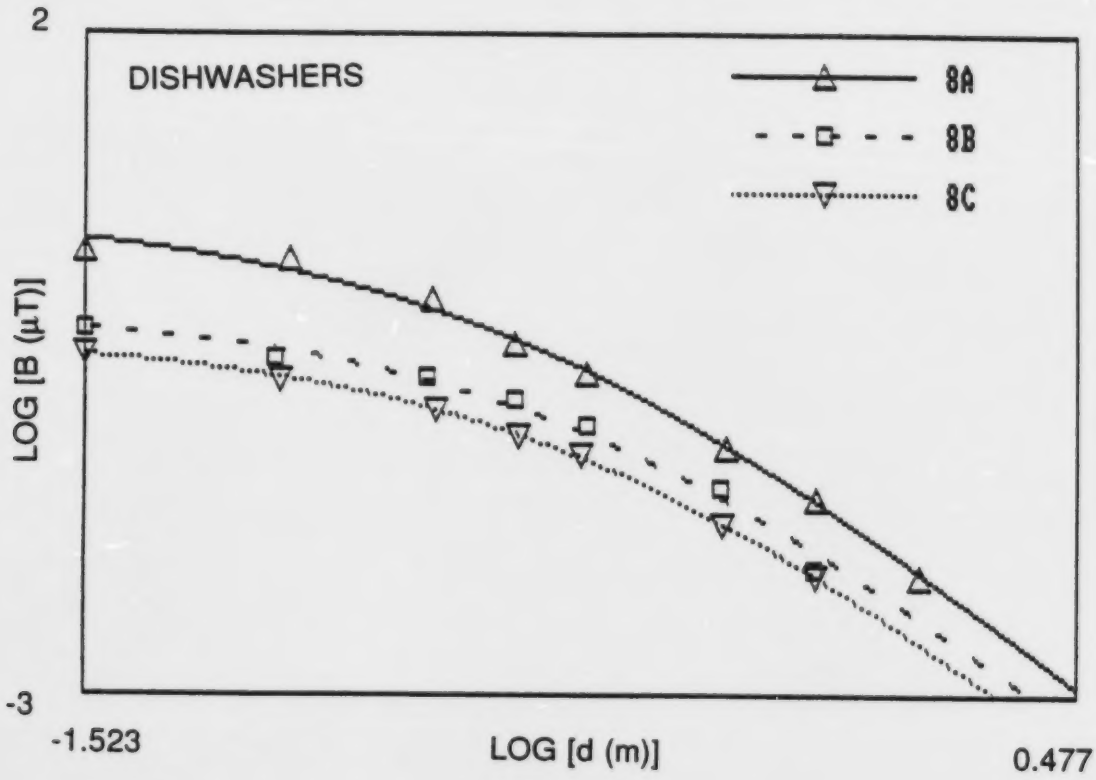

Figure 4(a). Magnetic flux density as a function of distance from appliance surface; data from Gauger (1985) and theoretical fits assuming a magnetic dipole source: Dishwashers (types 8A, 8B, 8C). Logs are to base 10.

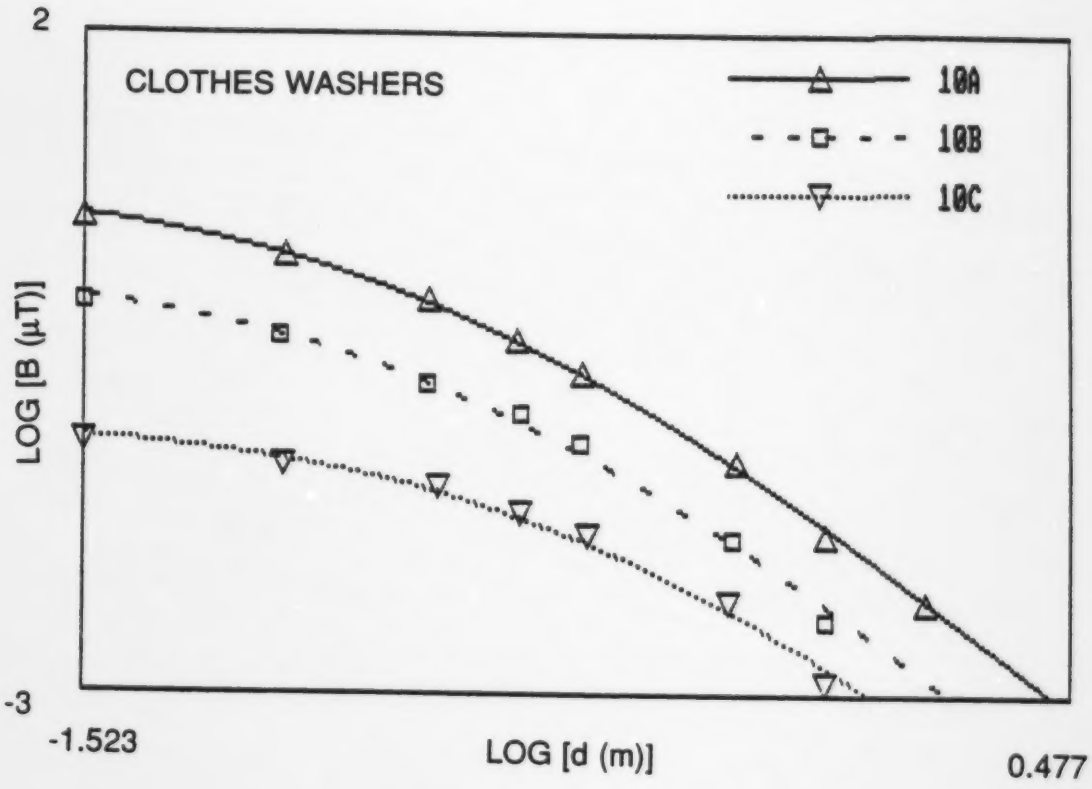

Figure 4(b). Magnetic flux density as a function of distance from appliance surface; data from Gauger (1985) and theoretical fits assuming a magnetic dipole source: Clothes washers (types 10A, 10B, 10C). Logs are to base 10.

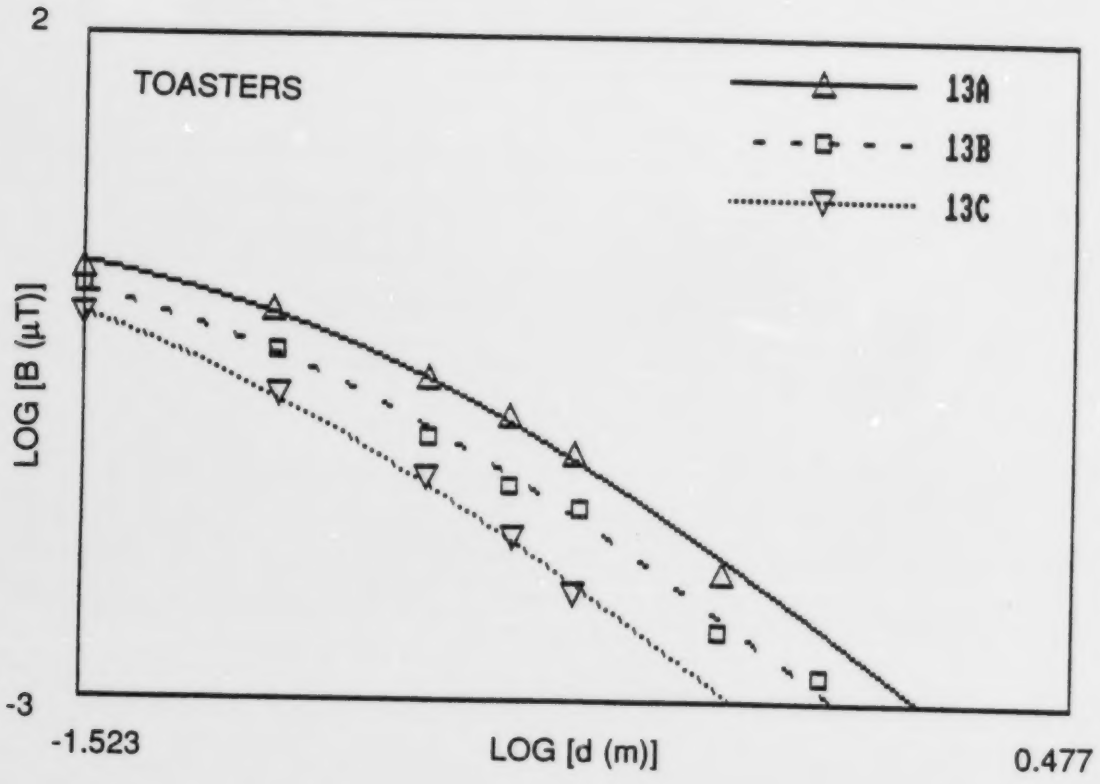

Figure 4(c). Magnetic flux density as a function of distance from appliance surface; data from Gauger (1985) and theoretical fits assuming a magnetic dipole source: Toasters (types 13A, 13B, 13C). Logs are to base 10.

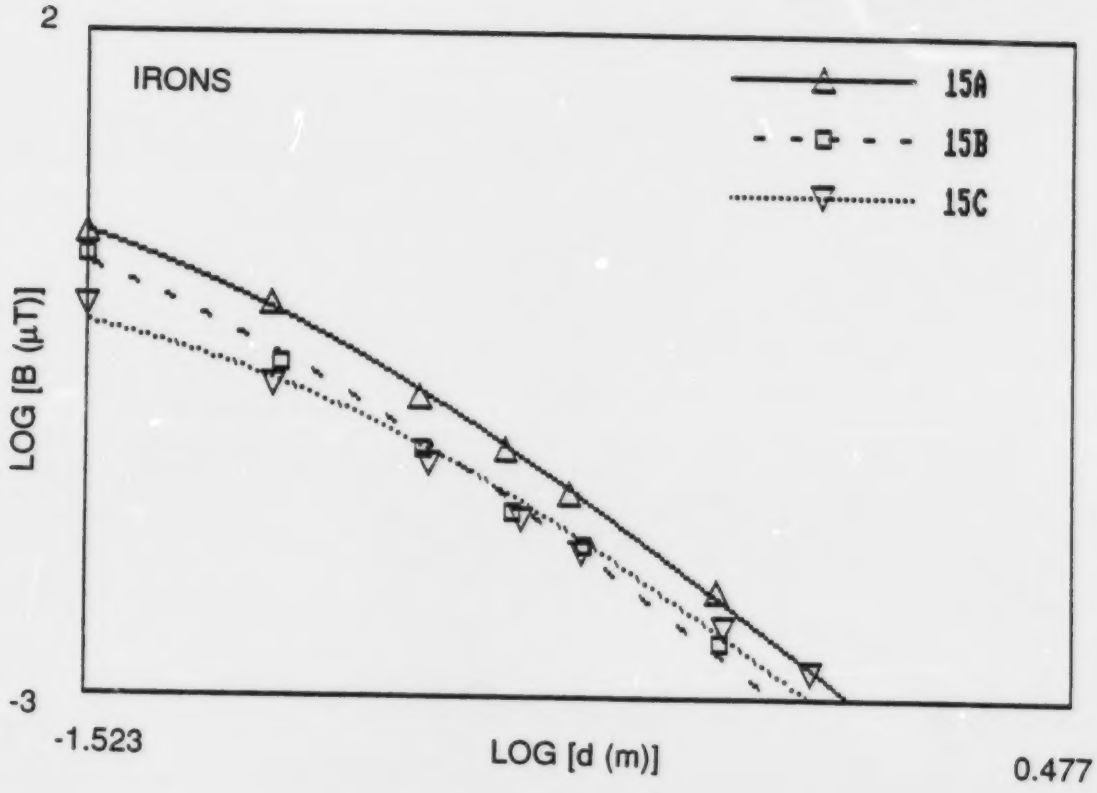

Figure 4(d). Magnetic flux density as a function of distance from appliance surface; data from Gauger (1985) and theoretical fits assuming a magnetic dipole source: Irons (types 15A, 15B, 15C). Logs are to base 10.

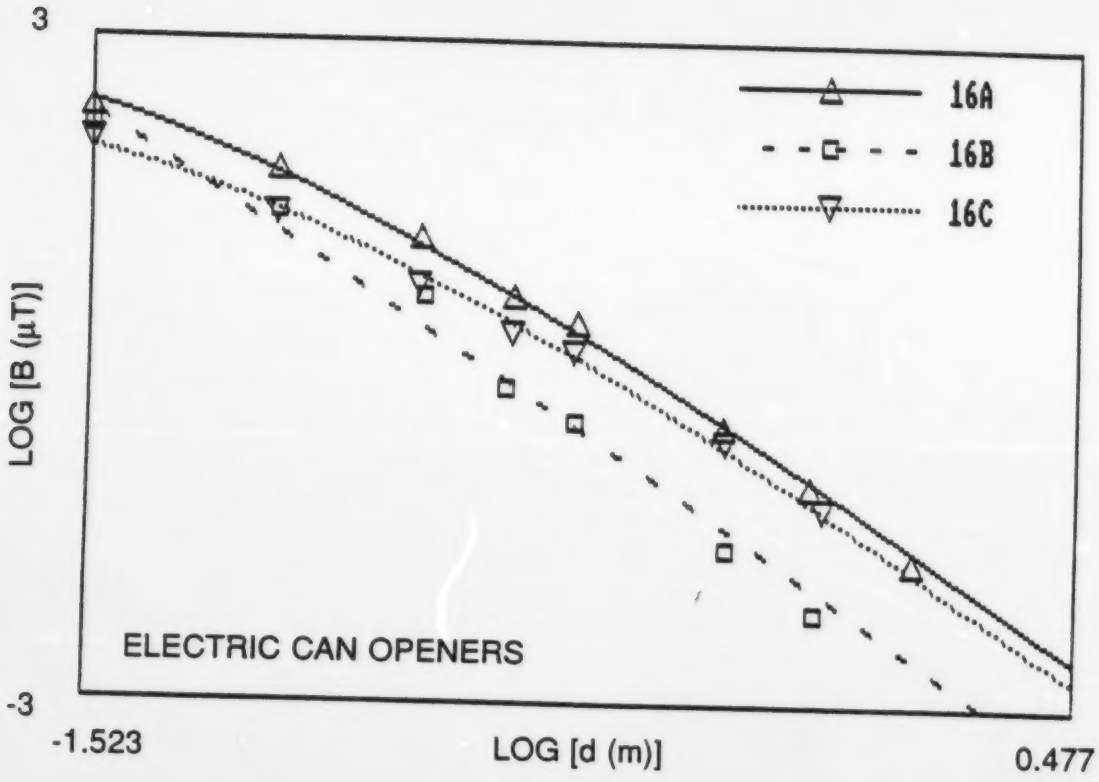

Figure 4(e). Magnetic flux density as a function of distance from appliance surface; data from Gauger (1985) and theoretical fits assuming a magnetic dipole source: Electric can openers (types 16A, 16B, 16C). Logs are to base 10.

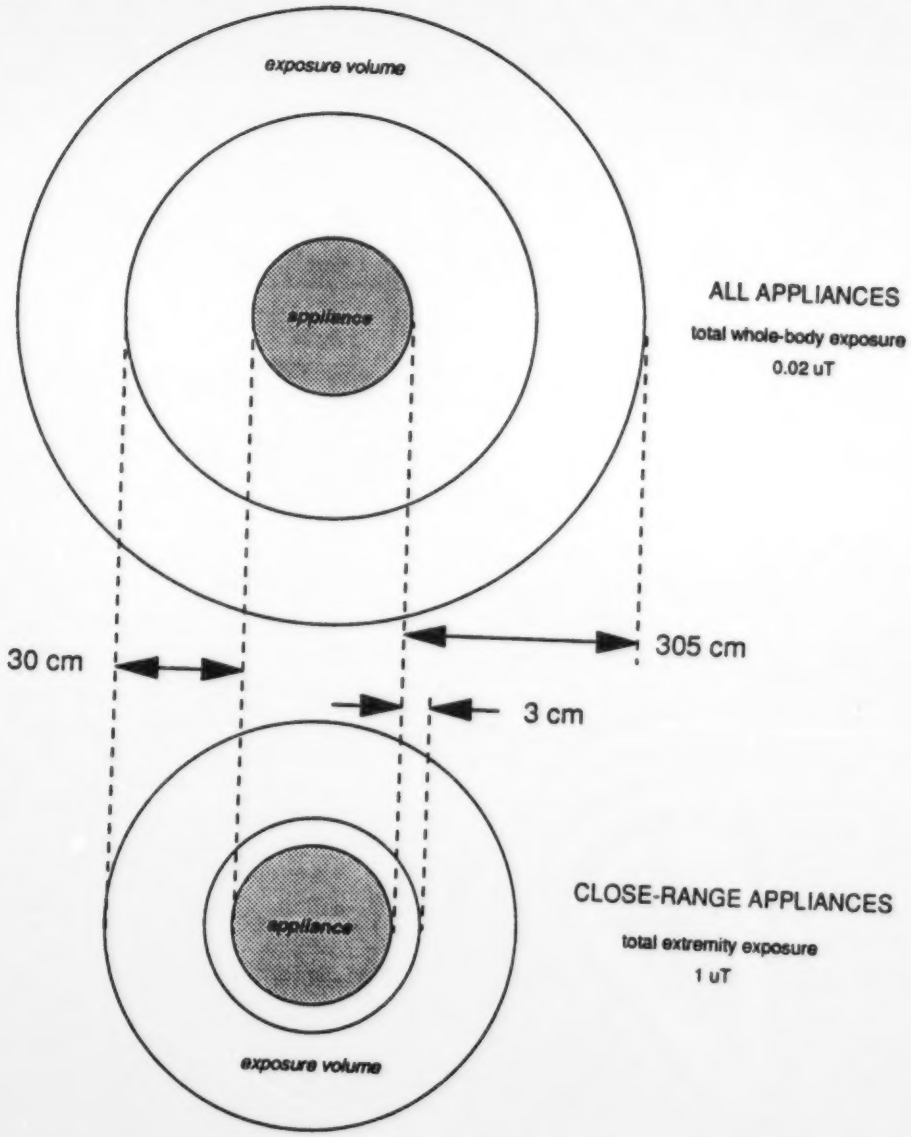

Figure 5. Application of spherical model (Figure 3) to Gauger's ensemble, for whole-body and extremity exposure.

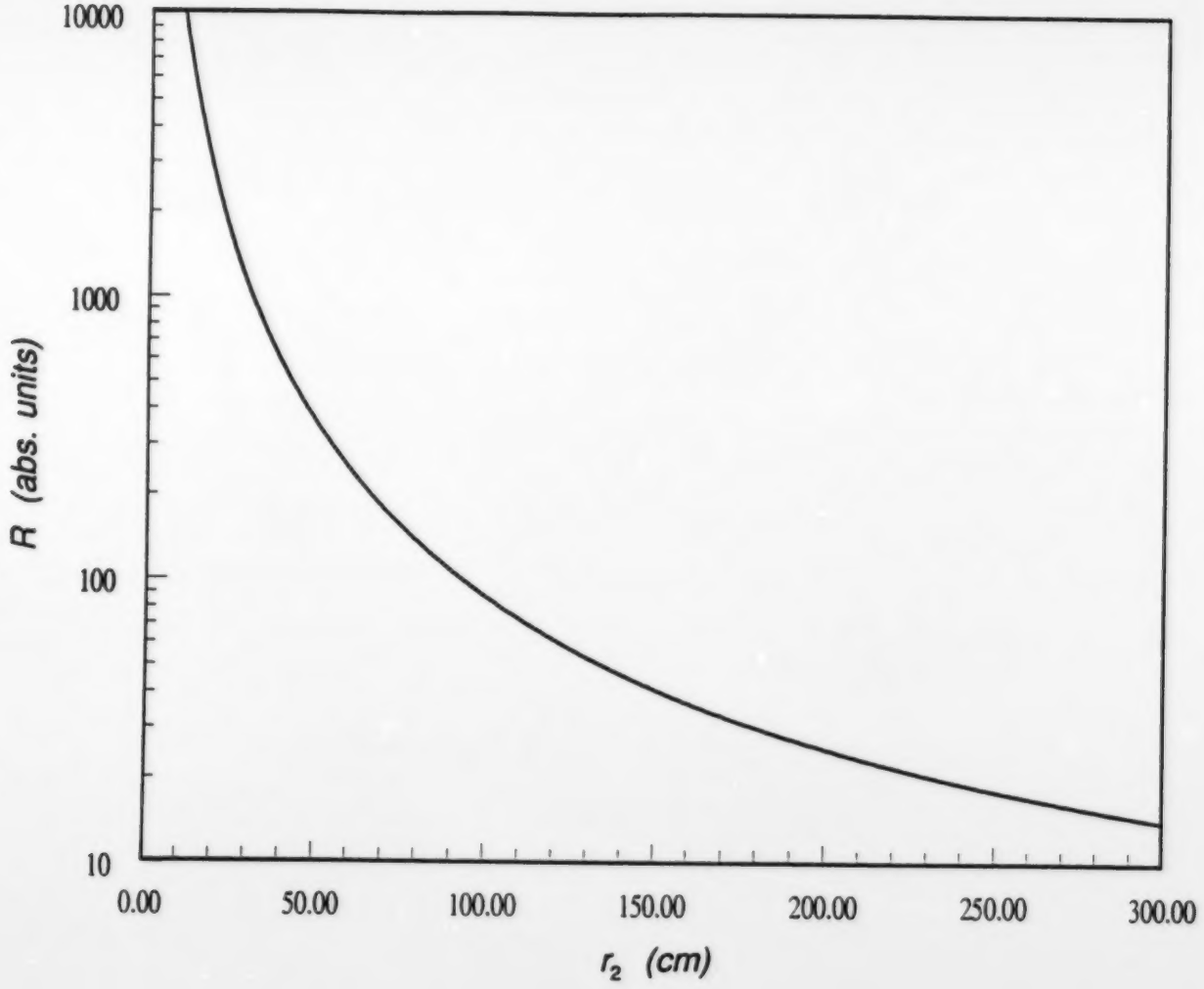

Figure 6. Ratio of extremity to whole-body exposure as a function of r_2.

TABLE 1.

Typical appliance usage patterns, and associated duty cycle.

Appliance	wattage	kW-hrs/mo	hrs/day	F_d
Range	12500	100	0.263	0.0109
Oven	12500	100	0.263	0.0109
Dishwasher	1300	18	0.455	0.0190
Refrigerator	300	100	10.965	0.4569
Clothes washer	500	8	0.526	0.0219
Clothes dryer	4800	80	0.548	0.0228
Microwave	1450	22	0.499	0.0208
Disposal	450	2	0.146	0.0061
Television	200	30	4.934	0.2056
Vacuum cleaner	800	4	0.164	0.0069
Coffee maker	900	6	0.219	0.0091
Toaster	1150	4	0.114	0.0048
Crockpot	-	-	0.083	0.0035
Portable heater	1000	30	0.987	0.0411
Portable fan	115	4	1.144	0.0477
Fluorescent fixture	100	12	3.947	0.1645
Fluorescent desk lamp	50	6	3.947	0.1645
Hair dryer	1000	4	0.132	0.0055
Shaver	-	-	0.083	0.0035
Iron	1000	12	0.395	0.0164
Can opener	175	1	0.188	0.0078
Mixer	125	1	0.263	0.0110
Blender	390	1	0.084	0.0035
Saw	275	1	0.120	0.0035
Drill	300	1	0.110	0.0046

TABLE 2.

Calculated magnetic dipole strengths and dimensions for appliances. *Type* designates Gauger's labels, and χ the deviation from Eq. (8).

Appliance	Type	2m (m^3-μT)	r_{appl} (m)	χ
Range	4A	0.14416	0.059	0.067
	4B	0.05668	0.049	0.096
	4C	0.02310	0.097	0.113
	4D	0.04721	0.134	0.102
	4CS	0.01856	0.096	0.303
Oven	5A	0.04319	0.169	0.090
	5B	0.05642	0.241	0.028
	5C	0.02922	0.281	0.048
Dishwasher	8A	0.38970	0.216	0.059
	8B	0.20593	0.300	0.090
	8C	0.13578	0.310	0.020
Refrigerator	9A	0.17480	0.475	0.098
	9B	0.04294	0.367	0.109
	9C	0.00380	0.156	0.108
	9C2	0.00225	0.147	0.250
Clothes washer	10A	0.20993	0.142	0.044
	10B	0.05519	0.147	0.084
	10C	0.03025	0.298	0.076
Clothes dryer	11A	0.01844	0.103	0.044
	11A2	0.01577	0.138	0.124
	11B	0.15194	0.629	0.042
	11C	0.06416	0.482	0.019
	11C2	0.04912	0.518	0.052
Microwave	6A	0.65742	0.130	0.050
	6B	0.78400	0.153	0.084
	6C	0.19325	0.079	0.211
	6D	0.34525	0.154	0.088
Disposal	7A	0.07296	0.034	0.066
	7B	0.03998	0.022	0.079
	7C	0.03375	0.045	0.095
Television	24A	0.07742	0.094	0.068
	24B	0.21732	0.188	0.075
	24C	0.22772	0.204	0.048
	24D	0.10831	0.176	0.036
	24E	0.00225	0.073	0.096

cont.

Table 2, cont.

Appliance	Type	2m (m^3-μT)	r_{spot} (m)	χ
Vacuum cleaner	19A	1.45966	0.107	0.148
	19B	0.08261	0.027	0.224
	19C	0.17479	0.046	0.107
	19D	0.11228	0.044	0.030
	19E	0.05705	0.031	0.240
Coffee maker	12A	0.00381	0.021	0.107
	12B	0.00466	0.053	0.080
	12C	0.02993	0.248	0.112
Toaster	13A	0.03925	0.098	0.072
	13B	0.01150	0.070	0.073
	13C	0.00284	0.043	0.059
Crockpot	14A	0.00573	0.055	0.135
	14B	0.00953	0.102	0.054
	14C	0.00571	0.119	0.060
Portable heater	20A	0.14022	0.070	0.074
	20B	0.11973	0.066	0.042
	20C	0.25341	0.106	0.040
	20D	0.00879	0.079	0.135
Portable fan	21A	0.01633	0.041	0.338
	21B	0.43304	0.213	0.088
	21C	0.00260	0.052	0.217
	21D	0.00887	0.107	0.114
	21E	0.00130	0.058	0.042
Fluorescent fixture	25A	0.00584	0.001	0.128
	25B	0.22354	0.109	0.091
	25C	0.01629	0.055	0.050
	25D	0.04916	0.120	0.080
Fluorescent desk lamp	26A	0.03703	0.019	0.142
	26B	0.03749	0.029	0.062
	26C	0.01524	0.014	0.094
	26D	0.23453	0.169	0.089

cont.

Table 2, cont.

Appliance	Type	2m (m^3-μT)	r_{eq} (m)	χ
Hair dryer	22A	0.22821	0.017	0.086
	22B	0.23311	0.046	0.080
	22C	0.00423	0.028	0.019
	22D	0.00322	0.030	0.014
	22E	0.00041	0.013	0.161
Shaver	23A	0.30987	0.027	0.040
	23B	0.21362	0.021	0.096
	23C	0.05746	0.022	0.091
	23D	0.05034	0.020	0.085
	23E	0.00248	0.023	0.052
Iron	15A	0.01506	0.049	0.047
	15B	0.00498	0.036	0.096
	15C	0.00862	0.080	0.155
Can opener	16A	0.86146	0.039	0.079
	16B	0.08389	0.004	0.227
	16C	0.52974	0.050	0.070
Mixer	17A	0.02879	0.004	0.061
	17B	0.35189	0.048	0.176
	17C	0.01821	0.045	0.057
Blender	18A	0.06551	0.048	0.068
	18B	0.09260	0.069	0.068
	18C	0.04727	0.050	0.084
	18D	0.03078	0.078	0.047
Saw	27A	1.02152	0.068	0.096
	27B	0.22383	0.035	0.072
	27C	0.03563	0.036	0.191
	27D	0.09054	0.029	0.071
	27E	0.02526	0.017	0.073
Drill	28A	0.08076	0.018	0.056
	28B	0.12841	0.031	0.059
	28C	0.11386	0.031	0.032
	28D	0.07379	0.027	0.051

TABLE 3.

Comparison of spatial averaging techniques.

Appliance	<B> (μT)	B_{rms} (μT)
(30 to 305 cm distance)		
Range	0.008742	0.031939
Oven	0.005512	0.014773
Dishwasher	0.029878	0.074227
Refrigerator	0.006789	0.016574
Clothes washer	0.013103	0.037416
Clothes dryer	0.006668	0.014366
Microwave	0.071030	0.233848
Disposal	0.007900	0.033627
Television	0.017793	0.056236
Vacuum cleaner	0.059604	0.240844
Coffee maker	0.001885	0.006542
Toaster	0.002754	0.010534
Crockpot	0.001060	0.003914
Portable heater	0.019873	0.073975
Portable fan	0.013830	0.049611
Fluorescent fixture	0.011349	0.043298
Fluorescent desk lamp	0.012692	0.050243
(3 to 30 cm distance)		
Hair dryer	12.02996	29.67290
Shaver	16.93913	44.70447
Iron	0.671534	0.887304
Can opener	60.55654	140.4447
Mixer	16.21525	37.06356
Blender	5.554677	9.255232
Saw	32.46812	69.31845
Drill	12.71828	31.37070

TABLE 4.

Whole-body exposures (averaged from 30 to 305 cm).

Appliance	<B> (μT)	B_{rms} (μT)
Range	0.008742	0.000095
Oven	0.005512	0.000060
Dishwasher	0.029878	0.000566
Refrigerator	0.006789	0.003102
Clothes washer	0.013103	0.000287
Clothes dryer	0.006668	0.000152
Microwave	0.071030	0.001477
Disposal	0.007900	0.000048
Television	0.017793	0.003658
Vacuum cleaner	0.059604	0.000408
Coffee maker	0.001885	0.000017
Toaster	0.002754	0.000013
Crockpot	0.001060	0.000003
Portable heater	0.019873	0.000817
Portable fan	0.013830	0.000659
Fluorescent fixture	0.011349	0.001866
Fluorescent desk lamp	0.012692	0.002087
Hair dryer	0.015306	0.000083
Shaver	0.020788	0.000072
Iron	0.001421	0.000023
Can opener	0.079767	0.000624
Mixer	0.021541	0.000236
Blender	0.009207	0.000032
Saw	0.044956	0.000156
Drill	0.016181	0.000074
Total whole-body exposure		0.016615

TABLE 5.

Extremity exposures from close-range appliances (averaged from 3 to 30 cm).

Appliance	<B> (μT)	B_{rms} (μT)
Hair dryer	12.02996	0.065953
Shaver	16.93913	0.058816
Iron	0.671534	0.011045
Can opener	60.55654	0.474281
Mixer	16.21525	0.177798
Blender	5.554677	0.019521
Saw	32.46812	0.112736
Drill	12.71828	0.058106
Total extremity exposure		0.978256